from the Cripple Creek volcanic centre are somewhat modified; the various rock types recognised by him are shown to be linked by intermediate forms; they are clearly all divergent eruptive facies of one general magma, characterised by containing from 9 per cent. to 15 per cent. of potash and soda, the soda being always somewhat higher than the potash; no true andesite is recognised. Most of the ore has come from the central area of phonolitic breccia.

The bulk of the telluride ore-bodies is in fissure veins, either simple or complex, being closely spaced and linked together, constituting what is called a "sheeted zone." The fissures radiate from a point to the north of the area; they are uniformly narrow, therefore the amount of gangue and ore is comparatively small. Quartz, fluorspar, and other minerals usually line the walls of the fissures; the rich tellurides are generally the last minerals to form. The authors consider that the unoxidised ore deposits represent the product of one period of general mineralisation not appreciably modified by any secondary enrichment. The last exhalation of the Cripple Creek volcano seems to be a mixture of nitrogen with about 20 per cent. of carbon dioxide and a small amount of oxygen. The gas increases in quantity with the depth, and in some cases interferes seriously with mining operations.

An interesting description of the petrography of the Highwood Mountains of Montana (7) is given by Prof. Pirsson. This region is occupied by a greatly eroded group of volcanoes which were in activity at some time subsequent to the Lower Cretaceous; several necks (stocks) are exposed, and now stand up as prominent peaks. Highwood Peak, the highest point in the group, is composed of syenite (pulaskose) and monzonite (shoshonose); in East Peak the rock is a basic leucite syenite. The Shonkin stock is shown to consist of Missourite, passing by intermediate stages into shonkinite. The Arnoux stock is important as the source of a new variety, *Fergusite* (fergusose), a rather coarse-grained, pseudo-leucitic augite rock, consisting of orthoclase, nepheline, and diopside; it appears to bear a similar relation to the leucitites that missourite does to the leucite basalts. In describing the petrographic characters of the necks, dykes, and extrusive flows, the new nomenclature is used concurrently with the old, so that the conservative reader need not be dismayed by "Trachyphyro-Highwoodose," "grano-shoshonose," or what not. The author concludes with some suggestive remarks on magmatic differentiation.

The annual report of the United States Geological Survey (8) is, as usual, a record of excellent organisation and of abundant energy in all departments.

The twenty-ninth annual report on the geology and natural resources of Indiana (9) contains a monograph of some 650 pages, by Prof. Blatchley, on the clays and clay industries of the State, the reports of the inspectors of mines and natural gas, a paper on the utilisation of convict labour in making road material, an account of the petroleum industry in Indiana in 1904, and a paper on the insect galls of Indiana.

The section on clays is very much like similar reports with which we are becoming daily more familiar; it is an excellent report of its kind. It describes in detail the clay resources of each county, with geological information and analyses; suggestions are given as to available clays and shales that are as yet unworked, and advice is given as to the best way of dealing with them. The use of bricks for road-making is strongly advocated, and the full specifications for the construction of brick pavements in the city of Terre Haute are given; these may prove of interest to those in this country who favour this type of road—the brick roads in Terre Haute have given great satisfaction. The report is illustrated with photographs and maps, and with full statistics of the various branches of the clay industry.

The paper on insect galls, by Dr. Cook, is little more than a catalogue of the galls known in the State. It is provided with a simple introduction to the subject and a bibliography, and with numerous outline sketches and photographs. It should be appreciated in the State. We are not aware that the papers mentioned above are issued separately; if this is not the case it seems unfortunate, for they appeal to such divergent interests.

The summary report of the Geological Survey of Canada (10) for 1904 indicates considerable activity in all quarters of the Dominion. A striking illustration of the usefulness of the survey lies in the discovery of a coal seam 10 feet thick in a bore-hole 2340 feet deep in Cumberland, Nova Scotia. This bore-hole was sunk through a thick cover of unproductive rocks at the suggestion of Mr. Hugh Fletcher, of the Geological Survey staff, after he had worked out the structural geology of the district.

In the Purcell Range, Dr. Daly records an enormous sill of hornblende-gabbro, 2500 feet thick; this he calls the "Moyie sill," from its occurrence at a point where the Moyie River crosses the international boundary. This great mass of basic rock has been thrust into the pre-Cambrian Kitchener quartzite, with the result that its upper portion, some 200 feet thick, has been converted into an acid biotite-granite by assimilation of the siliceous sediment. This has come about principally through the agency of "gravitational differentiation" following the shattering of the quartzite by the heated contact.

Prospecting for iron by means of the magnetometer (Thalen-Tiberg form), an innovation in Canada, seems to have had good results in Charlotte County, New Brunswick. Dr. Barlow contributes some notes on the occurrence of corundum in the intrusive complex of Robillard Mountain at Craigmont. The corundiferous rocks are of syenitic or gabbroid type; scapolite and nepheline often accompany or replace the prevailing felspars. Some of the syenite contains as much as 34 per cent. of corundum.

J. A. H.

THE PERIODICITIES OF SUN-SPOTS.[1]

EVERYBODY knows how to interpret the curve by means of which the intensity of radiation of a body is expressed in terms of the wave-length or frequency, and everybody recognises the utility of such a curve. It allows us at once to distinguish between the line spectrum and the spectrum of bands or the continuous spectrum, and brings out regularities which would be difficult to recognise in the original disturbance. In practice we employ the spectroscope to give us the data from which the curve of intensities is constructed. But what the spectroscope can do for a luminous disturbance, calculation can do for any quantity which fluctuates about a mean value. We are able, therefore, to construct in every case a curve which in all respects is analogous to the graph which connects the period and intensity of radiation. This curve I call the periodograph, and refer to the diagram embodying the curve as the periodogram. There is a periodogram of rainfall or barometric change, and these curves would, in my opinion, if constructed for different localities, yield us most important and characteristic information about climate.

During the last three years I have been occupied in calculating the periodogram of sun-spot variability. The results have been communicated to the Royal Society, and the following is a summary of abstracts which are published in the *Proceedings* of that society. The first paper deals with a detailed examination proving that the process I employ furnishes an analysis which is identical with the experimental spectrum analysis supplied by the grating. In the second paper the method is applied to the statistics of sun-spots.

The data used were Wolf and Wolfer's sun-spot numbers, which give us sufficient information from the year 1749 to the present time. I have in addition used, wherever possible, the measurements of areas which for each synodic revolution of the sun have been collected by the Solar Physics Committee of the British Board of Education from the year 1832 onwards, and the areas measured from photographs at the Greenwich Observatory for each day of the year since January 1, 1883.

The whole of the observations were treated collectively, but the complete interval of 150 years was also divided into two nearly equal portions, which were separately examined. At first sight, the results obtained by a com-

[1] Abstract of two papers, entitled, (1) "The Periodogram and its Optical Applications"; (2) "The Periodicity of Sun-spots." Read before the Royal Society on December 7, 1905.

parison of the two intervals of 75 years were exceedingly puzzling. While the observations beginning with about 1826 showed a nearly homogeneous variation of 11·125 years, this period seemed almost entirely absent between 1749 and 1826. Its place was during that interval taken by two important groups of periodicities, one of which had a periodic time of about 9·25 years, while the second had an average period of 13·75 years. The latter period was represented more nearly by what in spectroscopy is called a "band," extending from 13·25 to 14·25 years, but some of this want of definiteness may be due to the deficiency in observational data. For some time I was inclined to draw the conclusion that such periodicities as we observe are comparatively short lived, and replaced by a number of others which in their turn die out. A more detailed investigation, however, convinced me that the periodicities are, as regards the interval of time elapsing between successive maxima, extremely regular, occurring with what may prove to be astronomical accuracy. The key of the solution is, I believe, to be found in the overlapping of a number of periods, all of which are regular as regards time, but vary considerably as regards intensity, so that one or other may for a certain number of years become inactive. Their real existence is proved by the fact that whenever they reappear after a period of inactivity, the phase of the renewed periodic action fits in exactly with the continuation of the old period.

A periodicity of about 4·78 years runs through the whole of the observations. Its amplitude being about one-sixth of that of the eleven-year period is too great to be accounted for by accident. It appears separately in the series of Wolf's numbers, ranging from 1749–1826 and from 1826–1900. It also appears in the series depending on the measurement of areas. The phases of the period as determined from these series are in good agreement, and even while I was inclined to question the permanency of the eleven-year period I never felt any doubt that during the whole length of 150 years this period has been acting. Its time, determined as accurately as possible from the combined records, was 4·81 years, but I believe that if greater weight were given to the more recent and more complete observations the number would be slightly reduced. As regards the main period, which has certainly given its character to the sun-spot statistics during the greater part of the last century, I find the time as determined from the observations since 1826 alone to be 11·125 years. This agrees well with Wolfer's estimate of 11·124, and Newcomb's investigation, which led to 11·13 as the most probable number.

If to the most accurate series of measurements of sun-spot areas which begin in 1832 we apply a process the result of which is the elimination of the chief period, and draw a curve representing what is left, we find decided maxima during the years 1836, 1845, 1853, 1862, and 1870, the intervals being alternately 9 and 8 years, or 8·5 years on the average. The periodogram based on Wolf's numbers for the complete interval 1749–1900 shows a decided maximum of intensity for a periodicity of 8·25 years. Adopting this period provisionally, and disregarding all observations since 1826, we may use Wolf's series previous to that date for the determination of the phase of the period in question, and thus forecast the maxima for the subsequent interval. We thus obtain 1836·3, 1844·7, 1852·9, 1861·2, 1869·4, in almost exact agreement with the above. The slight disagreement of phase would be corrected by assuming the time to have been 8·32 years.

A periodicity of about 13·5 years shows as a maximum of intensity in the periodogram for the complete interval. In connection with it the following facts seem remarkable. There are in Wolf's records three cases of successive maxima having an interval of between 13 and 14 years. They are:—1626·0–1639·5, 1816·4–1829·9, 1870·6–1883·9. Also the interval between 1639·5 and 1816·4 is thirteen times 13·61, and the interval between 1829·9 and 1870·6 is three times 13·57. Thus the maxima all fit in with a period of about 13·6 years, which with varying intensity seems to have run through the whole record of observations.

Not wishing to lay too great a stress on what may prove to be merely a numerical coincidence, I return to the three periods which have been determined with some accuracy. It was only after the periodic times had been independently determined that the following remarkable relationship between the numbers was discovered. Taking frequencies into consideration, we are led to form the reciprocals of the periodic times, and thus find

$$1/11{\cdot}125 = 0{\cdot}08989$$
$$1/8{\cdot}32 = 0{\cdot}12019.$$

Adding up we find

$$1/4{\cdot}76 = 0{\cdot}21008.$$

Hence the sum of the frequencies of two of the periods agrees within the possible errors with the frequency of the third period. But it is also found that the two first numbers are very nearly in the ratio of three to four, so that we may also express the three periodic times as sub-periods of 33·375 years. Thus

$$\tfrac{1}{3} \times 33{\cdot}375 = 11{\cdot}125$$
$$\tfrac{1}{4} \times 33{\cdot}375 = 8{\cdot}344$$
$$\tfrac{1}{7} \times 33{\cdot}375 = 4{\cdot}768.$$

How far this connection is accurate or approximate it is impossible to say at present, but the fact that the three periods which have been traced with a considerable degree of certainty should also bear a remarkably simple relationship to each other is worthy of note.

If we accept a period twice as long as that given above, we might account for other periodicities of which at present the times are only approximately determined; thus $\tfrac{1}{5} \times 66{\cdot}75$ would lead us to 13·34, in fair agreement with the period of 13·57 years which has been mentioned above. But the difference is greater than it should be, and at the present I do not wish to put forward the longer.

ARTHUR SCHUSTER.

NATURAL HISTORY AND ARCHÆOLOGY OF THE WATERLILIES.[1]

MR. CONARD has embodied the result of several years' work on the waterlilies in the sumptuous volume before us. The monograph opens with an historical account of the plants as they were known to the ancients, and then deals with the group from a modern botanical point of view.

An interesting part of the memoir deals with the morphology and development of the plants, and the reader will find much that is worth reading therein. It must be confessed, however, that, taken as a whole, this portion occupies a somewhat large number of pages in proportion to the amount of valuable information it contains. The structure of the root is given at some length, but one would have liked to see a comparative treatment given that embraced not only the roots of different species, but also those of an individual plant at various stages of the life-history. Possibly such an investigation might throw light on the nature or origin of the "Liorrhizic" character of the roots in the waterlilies. Mr. Conard gives a good account of the formation of the intercellular spaces and the diaphragms so characteristic of the order, and he mentions an interesting occurrence of stomata on the under surface of the aërial leaves that rise above the level of the water in *Nymphaea odorata* var. *minor*.

The occurrence of stipules is a point of some note, and it may be remarked that their absence from the early leaves of the seedlings detracts from their phylogenetic significance in the group.

A short sketch of the development of the flower is included in the monograph, and we think it might have been considerably extended with no small advantage. The flowers, as is well known, occupy a remarkable position in waterlilies, where they apparently replace a leaf. The author was led to adopt a suggestion made by Caspary as to the morphology of the flower which explains the anomaly and at the same time appears to fit the facts of development. The anterior sepal, which appears first, and often well below the others, is regarded as morphologically representing the bract, whilst the two lateral sepals are

[1] "The Waterlilies. A Monograph of the Genus Nymphæa." By Henry S. Conard. Pp. xiii+279. (Published by the Carnegie Institution of Washington, 1905.)